

Alveolar Bone Augmentation

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Abstract

Bones and teeth are the only structures within the body where calcium and phosphate participate as functional pillars. Despite their mineral nature, both organs are vital and dynamic. The aim was to remark the indications for *alveolar augmentation* after tooth extraction and prior the placement of endosseous dental implants.

The autograft, allograft, alloplast, and xenograft materials all have reported success, alone or in combination, for particulate bone augmentation. The particulate autograft is the gold standard for most craniofacial bone grafting, including the treatment of dental implant-related defects. Advantages of alveolar ridge augmentation with sufficient bone volume to adjust for uncompromised and esthetic implant placement, renders these procedures more than effective for majority of patients. Surgical reconstruction of the tissues and the procedure of ridge augmentation and subsequent placement of dental implant are necessary.

Introduction

Immediately after extraction the bony walls of the alveolus present significant resorption, the central part of the socket is partly filled up with woven bone and the extraction site becomes markedly reduced in size. Pietrokovski & Massler (1967) [1] and Schropp et al. (2003) [2] have shown that the edentulous site diminishes in all dimensions i.e. bucco-lingual, buccopalatal and apico-coronal. At the same time, the soft tissues in the extraction site undergo adaptive changes that clinically may appear as deformations of the jaw [3].

In health, the different structures of the alveolar process, the cortical and cancellous bone are constantly undergoing remodeling in response to functional forces acting on the teeth. Once teeth are lost, the attachment apparatus is destroyed, and the alveolar process, mainly the alveolar ridge, undergoes significant structural changes; these are referred to as "*disuse atrophy*" [3].

Alveolar ridge atrophy after loss of teeth occurs secondary to advancing age, to deterioration of general health, to systemic or metabolic diseases, and due to occlusion defects or to denture pressure. The condition causes serious problems for both the dentist and the patient. The toothless mandibular resorption or the high muscular attachments caused by senile atrophy produces unsuitable conditions for total denture [4].

Resorption of the edentulous or partially edentulous alveolar ridge or bone loss due to periodontitis or trauma frequently compromises dental implant placement in a prosthetically ideal position. Therefore, augmentation of an insufficient bone volume is often indicated prior to or in conjunction with implant placement to attain predictable long-term functioning and an esthetic treatment outcome [5].

Ridge augmentation methods are therefore very important developments and have so far been promising especially in view of the fact that life is increasingly prolonged especially in economically developed countries and the incidence of the disease is expected to further increase in

the future. Bones and teeth are the only structures within the body where calcium and phosphate participate as functional pillars. Despite their mineral nature, both organs are vital and dynamic [5].

According to Frost [4] the aims of alveolar ridge augmentation are:

1. to restore the function of the jaw in anterior, posterior, vertical and lateral directions,
2. to increase the bone tissue in cases where the mandibula has atrophied,
3. to create an optimal support for dentures and better distribution of the jaw's functional forces,
4. to provide biologic acceptance of implants or transplants,
5. to rehabilitate the dentures for efficient functioning and to produce better facial esthetics.

There seems to be no uniformity of opinion however as to which of the available methods provide the best anatomical and functional results. Among the methods proposed to restore the alveolar ridge, bone grafts were the first to be popularized. Kruger [6] who favored this method recommended iliac grafts. Although costal grafts can perhaps better be adjusted to the mandibular arch, there can occur 50% loss due to contraction. These results are akin to those of Steinhauser and Obwegeser [6] who concluded that significant amounts of atrophy and defects are observed of the mandibula or on the maxilla after bone grafting. Other studies have reported satisfactory results in general for treatment of atrophic ridge using hydroxyapatite with lesser percentages of neural injuries [7]. Postoperative ridge resorption is observed only in 4-10% of cases, a figure which compares favorably with other procedures aiming to correct alveolar ridge atrophy.

Principles of osteogenesis, osteoconduction, osteoinduction, osteointegration, osteoperception and osteopromotion

The principles of osteogenesis, osteoconduction, osteoinduction, osteointegration, osteoperception and osteopromotion can be used to optimize therapeutic approaches to bone augmentation and regeneration.

- *Osteogenesis* - this term means that primitive, undifferentiated and pluripotent cells are somehow stimulated to develop into the bone-forming cell lineage. One proposed definition is the process by which osteogenesis is induced. Osteogenesis has been described as the direct transfer of vital cells to the area that will regenerate new bone.
- *Osteoconduction* - the term means that bone grows on a surface. An osteoconductive surface is one that permits bone growth on its surface or down into pores, channels or pipes. Wilson-Hench in a report of Albrektsson [8] has suggested that osteoconduction is the process by which bone is directed so as to conform to a material's surface. Osteoconduction embraces the principle of providing the space and a substratum for the cellular and biochemical events progressing to bone formation. The space maintenance requirement for many of the intraoral bone augmentation procedures allows the correct cells to populate the regenerate zone.
- *Osteoinduction* embodies the principle of converting primitive, undifferentiated and pluripotential, mesenchymal-derived cells along an osteoblast pathway with the subsequent formation of bone. This term means that pluripotent cells are somehow stimulated to develop into the bone-forming cell lineage. This concept was established in 1965, with heterotopic ossicle formation induced by the glycoprotein family of morphogens known as the bone morphogenetic proteins (BMPs). A bone graft material that is osteoconductive and osteoinductive will not only serve as a scaffold for currently existing osteoblasts but will also trigger the formation of new osteoblasts, theoretically promoting faster integration of the graft. The most widely studied type of osteoinductive cell mediators are bone morphogenetic proteins (BMPs) [8].
- *Osteointegration* - Brånemark [9] introduced the term "osseointegration" to describe this modality for stable fixation of titanium to bone tissue. Osteointegration was originally defined as a direct structural and functional connection between ordered living bone and the surface of a load-carrying implant [10]. It is now said that an implant is regarded as osseointegrated when there is no progressive relative movement between the implant and the bone with which it has

direct contact [11]. In practice, this means that in osseointegration there is an anchorage mechanism whereby nonvital components can be reliably and predictably incorporated into living bone and that this anchorage can persist under all normal conditions of loading [12]. Osseointegration provides an attachment mechanism for the incorporation into living bone of nonvital components made of titanium. As a biological phenomenon it has been amply demonstrated and clinically tested, and is now widely accepted. The present range of clinical applications is:

- In the field of oral surgery - worldwide, more than 800,000 patients have been treated since 1965 until now with osseointegration dental reconstructions, according to Brånemark. The results indicate a clear superiority over conventional prosthodontics, with respect to long-term success rates [13];
- Facial prosthesis (extraoral applications of osseointegration include anchorage for craniofacial prostheses including ear, eye, and nose] and finger prosthesis etc.
- *Osseoperception* - is the term used to describe the ability by patients with osseointegrated fixtures to identify tactile thresholds transmitted through their prostheses. It is a phenomenon of importance in both dental and orthopaedic applications of osseointegration. The identification of osseoperception as a phenomenon of osseointegration was the result of work carried out in the dental sciences by Torgny Haraldson [14].
- *Osteopromotion* involves the enhancement of osteoinduction without the possession of osteoinductive properties. For example, enamel matrix derivative has been shown to enhance the osteoinductive effect of demineralized freeze dried bone allograft (DFDBA), but will not stimulate from the new bone growth alone [15]

Ridge augmentation and bone grafting

The placement of endosseous dental implants for prosthetic support requires adequate bone volume at the desired location. Defect morphology is an important consideration in selecting a method for ridge augmentation. Although iliac crest is used most often in major jaw reconstruction for implants, block grafts from the mandible have been used with favorable results for repair of smaller defects. Autologous bone grafts are the gold standard in repair of alveolar atrophy and bone defects [16]. Despite of this as they are the most predictable material, only a limited amount of autogenous bone can be procured from intraoral sites which may not be sufficient for complete fill of defects. Meanwhile, alloplastic materials, particularly bioactive glass, may represent a possible alternative to be mixed with autogenous bone for the treatment of intrabony defects. Some histological studies have shown that the use of bioactive glass induces a significant increase in newly formed cementum and attachment and that apical downgrowth of the junctional epithelium can be prevented. Results from clinical and histological studies also indicated that bioactive glass is easy to handle, biocompatible, has haemostatic properties, and osteoconductive as well as potentially osteoinductive effects [17, 18, 19].

Bone augmentation techniques and material

Alveolar ridge deformities are classified according to their morphology and severity. A classification for alveolar ridge defects has been described to standardize communication among clinicians in the selection and sequencing of reconstructive procedures designed to eliminate these defects:

- I class - defect has bucco-lingual loss of tissue with normal ridge height in an apico-coronal direction.
- II class - defect has apico-coronal loss of tissue with normal ridge width in a bucco-lingual direction.
- III class - defect has a combination bucco-lingual and apico-coronal loss of tissue resulting in loss of height and width.

Critical-sized alveolar ridge defects in the horizontal and vertical dimensions may occur following tooth loss, fractures, or pathologic processes. Such defects may compromise the ideal implant placement as prescribed prosthetically with an unfavorable outcome.

Bone augmentation techniques may be used for *the applications of extraction socket defect grafting, horizontal ridge augmentation, vertical ridge augmentation* [5], and *sinus augmentation* [19]. To maximize the results for each of these applications, a variety of different techniques is employed. They include particulate grafting, membrane use, block grafting, and distraction osteogenesis, either alone or in combination [5].

In the scientific literature bone augmentation techniques are referred to as: 1. Bone Augmentation with Barrier Membrane Technique; 2. Particulate Bone Grafting Technique; 3. Block Grafting Approaches; 4. Combination Approaches; 5. Ridge Expansion Techniques; 6. Future bone augmentation approaches likely (will use molecular, cellular, and genetic tissue engineering technologies).

Horizontal and vertical ridge augmentation [5] were described with the use of a variety of different techniques and materials. Although achieving comparable clinical outcomes for vertical ridge augmentation has been more challenging, success was demonstrated with the use of non-resorbable ePTFE membranes with autograft, titanium mesh with particulate grafts, forced tooth eruption, autogenous block grafting, and distraction osteogenesis. [20].

Grafting materials [5, 19] were categorized in one of the following groups: 1. No graft (coagulum); 2. Autograft block (extraoral or intraoral donor site); 3. Autograft particulate; 4. Autograft from bone trap; 5. Membrane alone (non-resorbable or resorbable); 6. Allograft (freeze-dried bone allograft [FDBA] or demineralized freeze-dried bone allograft [DFDBA]); 7. Xenograft (demineralized bovine bone mineral [DBBM], algae-derived, or coral-derived); 8. Alloplast (hydroxyapatite [HA], β -tricalcium phosphate [TCP], bioglass, or calcium sulphate); 9. Combinations (autograft + allograft, autograft + xenograft, autograft + alloplast, allograft + xenograft, or allograft + alloplast).

Jansen et al. [5] has evaluated a total of 2006 abstracts and 424 full-text articles. Studies with horizontal ridge augmentations were analysed as: (1) studies that reported on the augmentation procedure itself, and (2) studies that evaluated implant survival in horizontally augmented alveolar ridges. Seventy-six studies with vertical ridge augmentations were evaluated as full text. The efficiency of the augmentation procedure showed that 73% of the cases were without the need for additional grafting and the implant survival rates ranged from 95% to 100% (median 100%).

Socket Preservation Application - in the anterior maxilla, where the buccal plate often is extremely thin and friable, consistent bone resorption is found after extraction. To minimize bone resorption, less traumatic extraction techniques with socket augmentation, using a variety of particulate bone graft materials with and without membrane barriers, were reported that demonstrated significantly reduced alveolar ridge dimensional changes associated with these preservation techniques. To preserve the extraction socket architecture and to accelerate the timeline to final implant restoration, the technique of immediate implant placement at the time of extraction often is proposed. Immediate implant placement was shown to have a failure rate of <5%, which is comparable to delayed placement [21]. Socket preservation helps to maintain the alveolar architecture and significantly reduces the loss of ridge width and height following tooth removal [22].

If an autogenous bone transplant is too difficult to perform, other treatments such as *distraction osteogenesis* or fillings with various bone substitutes are thus generally performed. For bone regeneration, three conditions of proper scaffolds, efficient growth factors, and stem cells are needed. Bone substitutes are thought to be useful as proper scaffoldings [23].

Bone augmentation with barrier Membrane Technique The concept of GBR was described first in 1959 when cell-occlusive membranes were employed for spinal fusions. The terms “guided bone regeneration” and “guided tissue regeneration” (GTR) often are used synonymously and rather inappropriately. GTR deals with the regeneration of the supporting periodontal apparatus, including

cementum, periodontalligament, and alveolar bone, whereas GBR refers to the promotion of bone formation alone. GBR and GTR are based on the same principles [24, 25].

Conclusion

A large but heterogeneous body of literature was available regarding augmentation of localized bone defects in the alveolar ridges after including all levels of clinical evidence except expert opinions. The major development in esthetic dentistry, and more so the introduction of implant dentistry, led to significant developments aimed to regenerate or restore bony defects and bone loss in the edentulous ridge. Most clinical efforts in the developments in bone augmentation procedures are related to either simplifying clinical handling or influencing of biologic processes. Many techniques exist for effective bone augmentation. The approach largely is dependent on the extent of the defect and specific procedures to be performed for the implant reconstruction. It is most appropriate to use an evidence-based approach when a treatment plan is being developed for bone augmentation cases.

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